Chapter 18
Repeated-Measures
Analysis of Variance

PSY 295 – Oswald

Outline
• What are repeated-measures?
• An example
• Assumptions
• Advantages and disadvantages
• Effect sizes
• Review questions

Effects of Counseling For Post-Traumatic Stress Disorder (PTSD)
• Foa, et al. (1991)
  – Provided supportive counseling (and other therapies) to victims of rape
  – Do number of symptoms change with time?
    • Point out lack of control group
    – Not a test of effectiveness of supportive counseling
    • Foa actually had controls.

Effect of Counseling--cont.
– 9 subjects measured before therapy, after therapy, and 3 months later
• We are ignoring Foa's other treatment conditions and the control group.
Therapy for PTSD

- Dependent variable = number of reported symptoms.
- Question--Do number of symptoms decrease over therapy and remain low?
- Data on next slide

The Data

<table>
<thead>
<tr>
<th>Patient</th>
<th>Pre</th>
<th>Post</th>
<th>Follow-up</th>
<th>Subject Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>15</td>
<td>15</td>
<td>17.00</td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td>15</td>
<td>8</td>
<td>15.67</td>
</tr>
<tr>
<td>3</td>
<td>21</td>
<td>17</td>
<td>22</td>
<td>20.00</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
<td>20</td>
<td>15</td>
<td>20.33</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>17</td>
<td>16</td>
<td>21.67</td>
</tr>
<tr>
<td>6</td>
<td>27</td>
<td>20</td>
<td>17</td>
<td>21.33</td>
</tr>
<tr>
<td>7</td>
<td>21</td>
<td>8</td>
<td>8</td>
<td>6.33</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>10</td>
<td>15</td>
<td>19.67</td>
</tr>
<tr>
<td>9</td>
<td>18</td>
<td>18</td>
<td>3</td>
<td>10.33</td>
</tr>
<tr>
<td>Mean</td>
<td>23.89</td>
<td>15.67</td>
<td>13.22</td>
<td>17.59</td>
</tr>
<tr>
<td>s.d.</td>
<td>4.20</td>
<td>4.24</td>
<td>5.78</td>
<td>12.51</td>
</tr>
</tbody>
</table>

Preliminary Observations

- Notice that subjects differ from each other.
  - Between-subjects variability
- Notice that means decrease over time
  - Faster at first, and then more slowly
  - Within-subjects variability
Partitioning Variability

Total Variability

Between-subj. variability

Within-subj. variability

Time variability

Error variability

This partitioning is reflected in the repeated-measures ANOVA summary table.

Calculations

- \( SS_{\text{total}} = \sum (X - \overline{X})^2 \)
  \( = (21 - 17.59)^2 + \ldots + (3 - 17.59)^2 \)
  \( = 1114.51 \)

- \( SS_{\text{withinsubj}} = \sum (\overline{X}_s - \overline{X})^2 \)
  \( = 3(17 - 17.59)^2 + \ldots + 3(10.33 - 17.59)^2 \)
  \( = 3(13262) = 39785 \)

Calculations--cont.

- \( SS_{\text{withinsubj}} = SS_{\text{withinsubj}} - SS_{\text{between subj}} \)
  \( = 1114.51 - 397.85 = 716.66 \)

- \( SS_{\text{error}} = \sum (X_i - \overline{X}_s - \overline{X})^2 \)
  \( = 3[23.89 - 17.59]^2 + (15.67 - 17.59)^2 + (13.22 - 17.59)^2 \)
  \( = 9(62.452) = 562.07 \)

Summary Table

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bet-subj</td>
<td>8</td>
<td>397.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W/in-subj</td>
<td>18</td>
<td>716.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>2</td>
<td>562.07</td>
<td>281.04</td>
<td>29.09</td>
</tr>
<tr>
<td>Error</td>
<td>16</td>
<td>154.59</td>
<td>9.66</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>1114.51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Interpretation

- Note parallel with diagram
- Note subject differences not in error term
- Note $MS_{\text{error}}$ is denominator for $F$ on Time
- Note $SS_{\text{time}}$ measures what we are interested in studying

Assumptions

- Correlations between trials are all equal
  - Fairly close
  - Matrix shown below

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>Followup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>1.00</td>
<td>.637</td>
<td>.434</td>
</tr>
<tr>
<td>Post</td>
<td>1.00</td>
<td>.742</td>
<td></td>
</tr>
<tr>
<td>Followup</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assumptions--cont.

- Previous matrix might look like we violated assumptions
  - Only 9 subjects
  - Minor violations are not too serious.
- Greenhouse and Geisser (1959) correction
  - Adjusts degrees of freedom

Multiple Comparisons

- With few means:
  - $t$ test with Bonferroni corrections
  - Limit to important comparisons
- With more means:
  - Require specialized techniques
    - Trend analysis
Advantages of Repeated-Measures Designs

• Eliminate subject differences from error term
  – Greater power
• Fewer subjects needed
• Often only way to address the problem
  – This example illustrates that case.

Disadvantages

• Carry-over effects
  – Counter-balancing
• May tip off subjects

Effect Sizes

• Simple extension of what we said for $t$ test for related samples.
• Stick to pairs of means.

Review Questions
(These are NOT the only questions to study)

• What makes a repeated-measures design different from a between-subjects design?
• What happens to the error that is lost from the error term?
• Why don’t we test for differences between subjects?
• What assumptions are required?
Review Questions--cont.
(These are NOT the only questions to study)

• What does the Greenhouse and Geisser correction do?
• Why do we limit the number of $t$ tests we would run between means?
• What are the advantages and disadvantages of repeated-measures analysis of variance?

Review Questions--cont.

• Describe a study where repeated-measures would be profitable.
• Describe a study where repeated-measures would be a mistake.